§23. Non-boiling Heat Transfer and Boiling Crtical Heat Flux in High Speed Water Flow Concerning Divertor Cooling

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As plasma-facing components of fusion experimental facilities, high heat fluxes are encountered. In such facilities, the thermal management by appropriate cooling offers a key of solution for an overall system design. The flow boiling CHFs for the pressures (143~1500 kPa) and inlet subcoolings (0~150 K) at a flow velocity (0~4 m/s) have been measured by Sakurai et al.[1] for a 1.2 mm vertical platinum cylinder in water flowing upward in round test tube section of 1425 mm in length and 38 mm in inner diameter. The CHFs for subcoolings at pressures as a parameter increase with an increase in subcooling at each pressure. The CHFs are divided into first and second groups for low and high subcoolings. Though the CHFs for low subcooling belonging to the first group are dependent on the pressure, the CHFs for high subcooling belonging to the second group are almost independent of the pressures at each flow velocity except the low pressures near atmospheric. The trends of the CHFs for the subcoolings with the pressures as a parameter at a flow velocity are just the same with those of the pool boiling CHFs. It has been assumed that the flow boiling CHFs for low subcoolings occur due to the HI and those for high subcoolings occur due to the HSN in fully developed nucleate boiling regime.[1]

The objective of this investigation is to establish the database for high heat flux thermal management at the divertor plates of fusion experiment devices. The schematic diagram of experimental water loop is shown in Fig 1. The test section in the loop is a round tube of 1 mm i.d. × 47.4 mm long which is vertically oriented with water flowing upwards.

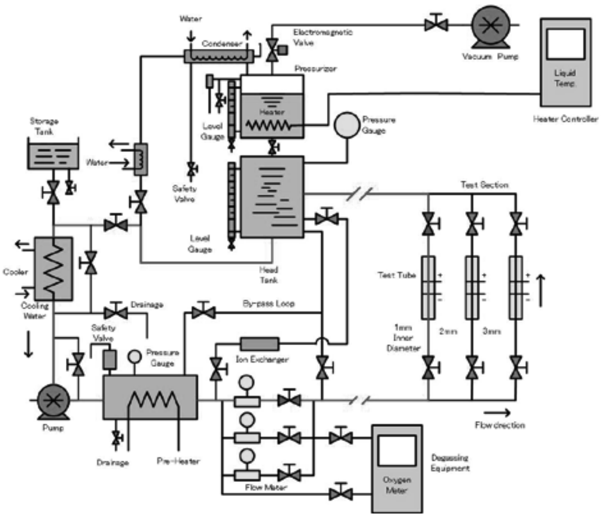

Fig. 1. Experimental apparatus

Figure 2 shows the heat flux versus inner surface superheat at the flow velocity of 9.8 m/s and the period of 9.2s.[2] The inlet subcooling is around 145 K. The heat flux increases with an increase of inner surface superheat. The dashed line shows a correlation of non-boiling forced convection heat transfer. The inner surface superheat of boiling incipient seems to be 7 K. The typical CHFs for period are ones for the inlet subcooling of 145 K at the inlet pressure of 986 kPa shown in Figure 3.[2] The CHF is gradually increasing with a decrease in period because the heterogeneous spontaneous nucleation surface superheat depends on the increasing rate of the surface superheat.[3] In other words, the trend of CHF with a decrease in period is due to a decrease in a depletion rate of conductive sublayer on an inner surface of tube. The transient CHF for the periods was expressed by a correlation obtained by Hata and Noda.[4] The experimental CHF values obtained are about 25% higher than those of correlation.

1)Sakurai et al. : 11th Int. Heat Transfer Conf.(1998)FB22.
2)Shibahara et al.: 1st PRTEC(2016)PRTEC-14766.
3)Sakurai et al. : ASME 95-WA/HT-17(1995)1-11.
4)Hata and Noda : J. of Heat Transfer 130(2008)1-9.

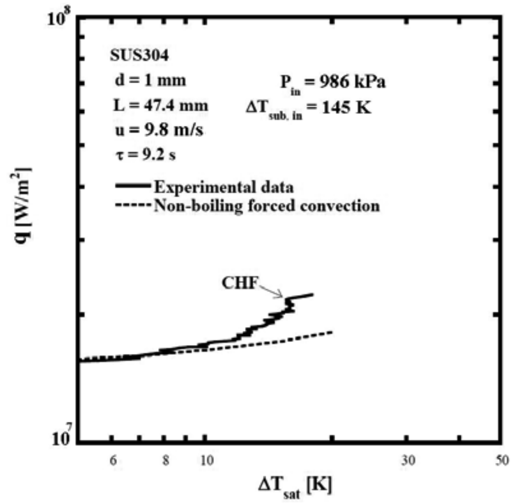

Fig. 2. Flow boiling curve[2]

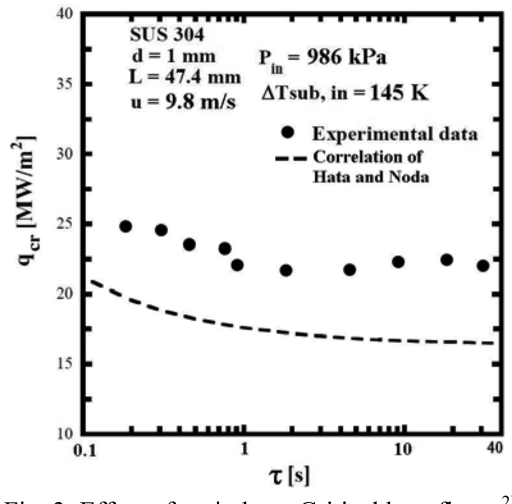

Fig. 3. Effect of periods on Critical heat fluxes[2]